UNIVERSITY OF CALIFORNIA
COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BERKELEY, CALIFORNIA

CIRCULAR 323

April, 1932

THE ROLE OF FIRE IN THE REDWOOD REGION

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A fire in felled redwood timber.

In the redwood region of California there is a very common apathy toward the prevention of fires on forest and cut-over lands. Many local residents believe that fires do no harm in the forest; some go so far as to claim that periodic burning of the forest is good for the trees and that it stimulates their growth. Some believe that exclusion of fires invites the growth of 'undergrowth' or shrubs which 'sap the vitality' of the trees and cause 'spike-tops' and eventually death. 'Old-timers' believe that in the early days fires were not so destructive as they are today because the more frequent burning kept the woods open. They claim that all of the forest was burned deliberately in

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those days every few years. These beliefs are fallacious as can be easily proved by close observation and correct interpretation of what one sees. The virgin redwood forest has been irreparably damaged by past fires; current fires aggravate the damage and on cut-over land they materially reduce its ability to produce new tree growth.[2]

The writer has endeavored over a period of twelve years of close contact with the redwood region to study the influence of fires, and he has come to the conclusions herein reported.

PAST FIRES

Fires ran through redwood forests long before the white man arrived. On one experimental plot individual fires have been dated back by wound tissues on stumps to over 1,200 years ago. They have become more prevalent and on the whole more severe since the arrival of the white man. The stories of old residents of the redwood region concerning the acts of the Indians are conflicting. Some believe that the Indians set the woods afire every season that there was a sufficient accumulation of litter to support a fire—every four or five years, according to them—and that the course of an Indian traveling through the woods could be charted from a distance by the succession of smokes as he set fires. Others say that the Indian was afraid of fire and set it only to drive game or to burn out his enemies, or that his prairie fires escaped into the woods. Others argue that Indians set fires deliberately to make travel easier. Many white men ascribe to the Indian superior powers of intelligence and a forestry knowledge not equalled by present-day students of the forest. This group believes that 'Indian forestry,' or frequent burning, is a type of fire-proofing *by the use of fire* and that it is the only type of forestry that should be practiced in the standing timber today. The early Indian of the redwood region was of a lethargic type. No doubt he did occasionally set wood fires for a period of many centuries but it is extremely doubtful that he did it with any thought in mind of improving or safeguarding the forest for the trees themselves. He was not a malicious or willful destroyer, yet his fires were doubtless set for his own convenience or needs rather than for the welfare of the forest. The redwood forest has survived in spite of many pre-white-man fires, the causes of which can only be surmised. Were it

[2] Brief mention of fire in the redwood forest is made in: Fisher, R. T. A study of the redwood. *In:* The redwood. U. S. Bureau of Forestry Bul. 38:1–28. 1903. Kellogg, A. Essay upon redwood. *In:* Redwood and lumbering in California forests. Edgar Cherry & Co., San Francisco. p. 77–107. 1884.

not for the remarkable fire resistance of the redwood species and its great vitality it would have succumbed to such treatment long ago. The many fires of the past (fig. 1) are responsible for the very ragged appearance of the present-day forest, the many hollow-butted trees, and most of the heart rot.

Unless Indians set them, it is difficult to explain the causes of fires of centuries ago except by spontaneous combustion or lightning.

Fig. 1.—A heavy stand on the Redwood Highway showing characteristic fire damage to the lower portions of the trunk. A tree hollowed by fire stands about 50 feet to the right of the road. Many others are deeply burned or scarred at the base. Individual trees in this group are as large as 10 feet in diameter at breast height and through their 500 years or more of life have withstood many fires.

The region is too moist for us to give credence to the spontaneous combustion theory, likewise it is one of very infrequent lightning storms during the dry season. Normally it is difficult to start a fire in the virgin redwood forests except with some preparation. Occasionally, however, there come times, such as the disastrous September of 1923, of very low humidity accompanied by high temperature during which fires start very readily. When they occur during seasons of exceptional drought such as 1923, 1924, 1929, and 1931, there is great danger of small fires reaching catastrophic proportions. Lightning-struck trees are extremely rare. There are only a few authentic reports of fires started by lightning. Mr. W. G. Corbitt, forester of the Pacific Lumber Company, recorded an electrical storm on

August 27, 1923, which he believes started several fires in Humboldt County. He traced one smoke himself to a 6-foot redwood tree, 80 feet of the top of which had been broken out by the bolt and shattered,

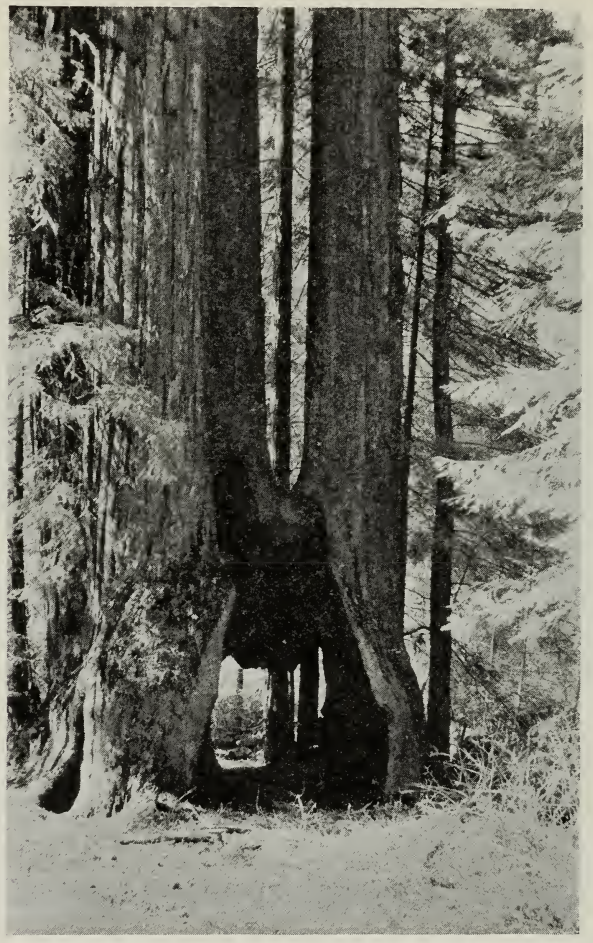

Fig. 2.—A compound tree, the common base of which has been reduced to a mere shell by repeated fires. Such trees carry large quantities of rot in the heartwood above the cavity and are in constant danger of being wind-thrown. The felling of such trees during logging is several times more costly than felling normal trees, and the danger to the choppers is greater.

and found fire burning in the fragments scattered on the ground about the tree. This storm was accompanied by showers. Since the storm of August 27, 1923, Mr. Corbitt has recorded several lightning storms, but he does not know of any fires having resulted from them. Mr. V. B. Davis, forester for the Union Lumber Company in Mendocino

County, reports the occurrence of an electrical storm on August 25, 1923, and one on September 1, 1924. One of his fire patrolmen reported the 1923 lightning to have struck in five places and to have been followed by fire at three of them. Two of these fires occurred in virgin timber and, in size, were held under three acres each. The third occurred in a tanbark oak slashing and covered fifteen acres. The 1924 storm was seen by the patrolman to strike in cut-over land on a high point and to start a fire which covered three thousand acres before it was put under control. On May 24, 1931, the weather observer at Fort Ross in Sonoma County reported to the U. S. Weather Bureau that lightning struck a 4-foot redwood tree and shattered it to within 13 feet of the ground. It is thus possible that some of the early fires were started by lightning, but it seems highly improbable that more than a few were so caused. It may be expected, however, that lightning will play a much larger rôle in the future, principally because of the presence of much logging débris and many tall snags on cut-over land.

Fire history was studied by the author in 1928 on over 100 stumps on an area of 30 acres in Humboldt County, and the conclusion drawn that during the past 1,100 years there were at least 45 severe fires in that particular locality or at least 4 each century. The data, obtained from ring counts, indicate many more fires, but the exact dates of past fires cannot be determined very accurately because redwood appears to produce only partially continuous rings, or possibly none at all, at the stump height during some years, although in the same years it may produce fairly wide ones in the top logs. There is danger, therefore, of counting some fires more than once. The figure given above has all possible duplicates eliminated and is considered to be very conservative.

Past fires burned into certain trees very deeply but wounded others only slightly or not at all. This refers to the stump section. Doubtless if the stumps had been cut lower, scars of additional fires would have been exposed. It is evident from field studies that in each fire some trees escape damage entirely or nearly so, but that the same trees may suffer severely in another fire. Each tree thus does not record all the fires of its immediate locality. Trees of great age—over 1,000 years—are often sound to the heart and show only a few fire scars. Doubtless such specimens owe their long life and freedom from more frequent injury to a combination of chance and a particularly thick, dense, and resistant layer of bark. As above noted, it is difficult to determine, without very costly study, the exact number of fires in the past, or their frequency. Judging from the

huge holes in many hollow trees, and the fact that ordinary wounds heal rapidly in the redwood, it is certain that the fires were frequent and severe enough to prevent healing and to cause mere scars to become gaping holes.

PAST FIRES THE CAUSE OF HOLLOW TREES

Fire is responsible for the 'goosepens' or hollow-butted trees (fig. 2) so common in the region. A light fire may kill the delicate cambium layer by heating, without burning through the bark, because frequently recurring fires reduce bark thickness materially. Ordinarily the ridges of the basal bark are very heavy and fire resistant,

Fig. 3.—A striking example of the relation between fire and rot. The stump of a tree hollowed by repeated fires. Its outside top diameter is nearly 12 feet, while the thickness of the shell varies from 12 inches to 36 inches. The cavity extended 20 feet above the stump top. The butt log shown at the right was cut 24 feet long, and was crushed during logging and became a total loss. See also figure 4.

occasionally from six to twelve inches thick; but in the depths of the furrows on thrifty trees the bark is soft, succulent, thin, and easily destroyed. Unless it is burned completely off, the bark continues to cover the killed area, but as wound callus is formed and it encroaches from the sides the dead bark is pushed outward. The annual rings of the callus are particularly wide and before the wound is entirely covered with new wood there may be a space of several inches between the old bark and the dead wood. The sapwood on the scar becomes decayed, and the bark dries out and later cracks under the stretching

force of diameter growth. If the next fire occurs before the wound is safely healed it finds excellent fuel—dry bark and rotten sapwood. It burns away this bark, eats into the rotten sapwood, and thus starts a cavity. The fires that follow, if frequent enough, progressively burn the hole larger, the rate of increase accelerating at a more rapid rate than the occurrence of fires. Thus are formed goosepens, many of them over four feet wide and a few over eight feet (fig. 3). Some of them actually have been used for the shelter of small domestic animals and the storage of vehicles. Not uncommonly, fire travels up a trunk killing only a long narrow strip of bark. For example, a 12-foot leaning tree on Bull Creek Flat near Dyerville has a deadened 12 to 24-inch strip extending over 100 feet above the ground. The fire occurred since 1924 and the bark is now loose and the sapwood exposed and partially decayed. The effect of this on the future of the tree is obvious.

FIRES RESPONSIBLE FOR HEART ROT

Fire is responsible for over 90 per cent, in fact, probably more nearly 100 per cent, of the 'dry rot'[3] in the lower portions of the trees. This rot gains entry through the open fire scars and prepares better fuel for the next fire. Once a goosepen is formed and rot has entered, the combined action of recurring fires and advancing decay causes the tree to become weakened and eventually to topple over. Death in such cases is due primarily to fire rather than to decay, since the latter follows fire. The heart rot is not a tree-killing disease, but it is a very important factor in weakening a tree mechanically.

FIRE A CONTRIBUTORY CAUSE OF 'SPIKE-TOPS'

Fire contributes to the formation of many of the spike-topped trees so common in old stands. Some residents believe that the reduction in fires during the past few decades in some localities has encouraged so much competing undergrowth as to deprive the larger trees of sufficient moisture so that they die back from the tops. This is incorrect, of course. The undergrowth is actually an important aid in maintaining good soil conditions for thrifty tree growth in stands that lack density. In dense or well-stocked stands undergrowth is not likely to develop. Fires themselves may be the

[3] Fritz, Emanuel, and Lee Bonar. The brown heart rot of California redwood. Jour. Forestry 29:368–380. 1931.

primary cause of undergrowth on the typical old-growth redwood site since they so thin out the tree population as to admit sufficient light to encourage shrubby species and young trees. In some cases, fires of the past have swept up along the trunks on the shreds of bark that have weathered loose and have killed the tops where the protecting bark is less than one inch thick. A contributory cause of spike-tops is the killing of a part of the basal cambium by fire and the consequent reduction of the active water-conducting sapwood area, resulting in too little moisture reaching the top to keep it alive.

Fig. 4.—The butt log of the tree, the hollow stump of which is illustrated in figure 3. It was cut 24 feet long and the cavity extended to within 4 feet of the small end and its rot extended from the top of the cavity into the third log. The second log, 18.7 feet long, scaled 4,920 board feet gross and the loss chargeable to rot was 2,690 feet. The third log, 21.4 feet long, scaled 4,375 feet gross and the rot loss was 1,030 feet. The rot gained its entry at the burned base and was attributable first to fire.

Fires are not, however, responsible for all the spike-tops among the veteran trees. The death of many is doubtless a physiological phenomenon. The author offers the theory that after the tree has attained its ultimate height and begins to extend its topmost branches and to increase the area of the foliage a point is reached where the demand for moisture is greater than the tree can meet. The topmost parts thus are caused to die in the readjustment that must take place. As fire protection is improved, the formation of additional spike-topped trees will be limited to physiological or natural causes. It is not at all unlikely that dry spike-tops serve to attract lightning but there is no evidence, in the case of redwoods, that they are more susceptible than green tops.

THE LOSS TO MERCHANTABLE CONTENTS

Fires, past and present, are responsible for a large part of the quantity of 'short-lengths' that develop in the sawing up of the logs. Fires occasionally are responsible for the loss of entire butt logs in the case of hollow trees, as shown in figure 4, and additional logs infected by fire-induced rot. Past fires have reduced the merchantable contents of commercial stands on an average by at least 15 per cent, a figure arrived at by measuring on actual felled trees the loss due to fire scars and consequent decay.[4]

FIRES AFFECT COMPOSITION OF THE FOREST

The present composition of a typical virgin redwood forest as to size and age is, to some extent at least, due to fire. Without the fires of the past, the general average of age and diameter would be greater than it is at present. Certainly there would be no hollowed butts and very little butt heart rot. Without fires many more trees would have had an opportunity to reach diameters of over 15 feet and ages up to and over 2,000 years before they become so top-heavy as to topple over in a wind. Since the species has no important tree-killing insect or disease enemies, and since it naturally has great longevity, the forests should contain many more large and old trees than at present.

Fires are probably responsible for the admixture of Douglas fir and white fir which reproduce from seed more readily than the redwood and which gain entrance in openings left by the falling of burned-off veterans. Without fire there would be fewer openings and fewer opportunities for the other conifers to enter. Only the redwood (and spruce in the northern sections of the region) can exist in the dense shade and bide its time for a falling veteran to make way for it. White fir and particularly Douglas fir are less able to endure shade and have less longevity than the redwood. They, therefore, should have difficulty in maintaining themselves on sites suited to good growth for the redwood. This is well proven on the 'flats' on which there apparently have been fewer fires and where there are larger trees and more of them. The redwood here occurs in pure stands and the crown canopy is too dense to permit the entry of Douglas fir and white fir. These species do not grow so tall as

[4] Data confirming this statement will appear in a later publication now in manuscript form.

redwood and consequently are eventually eliminated, but where fires cause openings they readily enter and attain large dimensions. Because of their better seeding and germinating powers, Douglas fir and white fir would doubtless have been represented, to some extent anyway, where redwood, for adverse site reasons, could not keep it out. Given an equal start and opportunity the three species will develop with nearly equal speed until they reach the culmination of their height growth, after which redwood has the advantage. The influence of fire upon the composition of the redwood forest offers an interesting field for special study.

Redwood 'flats,' as the river benches are called locally, have apparently been visited less frequently by fire, and fires that have occurred have been less destructive. There are fewer goosepens on the flats than on the slopes, and windfalls show very few fire scars at cross sections. The average diameter is greater than on slopes. The crown canopy is often so complete on the flats that undergrowth is sometimes limited to a carpet of oxalis. Flats thus present excellent demonstrations of fire influences, although the richer growing conditions must be given their due share of the credit for the better growth, while the superior shade tolerance and longevity of redwood must be considered in judging the reason for the purity of the type. It must not be inferred that flats are a safe fire risk. Fires have occurred in them in the past and will occur again. Because of their accessibility flats are visited more frequently by tourists and campers and therefore should be kept clear of heavy accumulations of débris or protected by other means.

There are areas of redwood, such as in the Freshwater Creek basin in Humboldt County, in which there have been no fires for perhaps 200 years as indicated by wound tissue and the age of underbrush. On such areas the timber is particularly large and the stand is dense; and being usually well watered they support in addition a dense undergrowth of shade-enduring shrub species. In 1929 near the close of an unprecedented period of drought, fires ran into this basin from several points and burned fiercely for several weeks. Jointly, these fires covered over 10,000 acres. The fires felled many large trees and severely injured many more. Each fire burns old goosepens larger and causes more trees to fall. The fallen trees are not removed until the advancing logging operations reach them. In that time the sapwood and some of the heartwood have become checked and decayed and the trunks are later burned more deeply in the usually inevitable slash fires than if they had been freshly felled. In one case fires burning through a 40-acre old-growth redwood stand caused

the falling of nearly two per cent of the trees over four feet in diameter, by actual count. Surveys on larger burned areas substan-

Fig. 5.—Illustrating fresh sprouting after fire had killed the branches. Such trees are called fire columns. The tall snag in the center is hollow for over 30 feet from the ground but is still alive with a 16-inch sprout growing from its side and reaching above its top. The picture well illustrates the vitality of redwood. All trees left standing were pulled down during logging. It is improbable, however, that had they remained standing they would have recovered from the shock of fire sufficiently to develop into merchantable trees in a second cut.

tiate this estimate. These fallen trees add to the difficulty of felling when later the area is to be logged off, and increase the tree breakage as well as the cost of logging.

FIRES AFFECT SPROUTING AND THE SUCCESS OF SEEDLINGS

Fire induces sprouting. Trees subjected to great heat in a slash fire and not killed will lose all their foliage, twigs, and smaller branches but will likely sprout profusely along the trunks from near the ground to the top and on many of the larger branches that escaped killing (fig. 5). Such sprouting arises from thousands of adventitious buds stimulated to growth by the killing of the normal buds. A tree subjected to less heat and not to direct flames may lose all its foliage

Fig. 6.—A cut-over area one year after logging and burning. The tree growth at this time was limited to sprouts from some of the redwood stumps. These sprouts appear as dark clumps in the illustration. The unmerchantable trees were broken down during yarding; the trees remaining on the ridge line were not reached by the logging equipment. Fire has consumed all the organic litter, but has left the large branches, tops, and broken logs.

but will sprout only from the original buds. Trees that sprout for their full length are known as 'fire columns,' and give rise to low-grade lumber. This observation has a particularly important bearing on areas that are to be selectively logged and where a residual stand is to be saved for a future crop. The trees remaining must be protected against fire during and after logging if they are to be depended upon to produce lumber for a future second cut.

Fires in virgin timber frequently start sprouts from near the ground line (fig. 6). Some of these sprouts reach pole size and materially interfere with the growth and later the felling of the parent tree and must be cut down and sacrificed before the 'choppers,'

or 'fallers,' can get at the big tree. After logging, a large percentage of redwood stumps sprout vigorously. Subsequent fires kill back such sprouts, and some stumps fail to resprout; many of them, however, can withstand an occasional light fire and will resprout with remarkable persistence and vigor.

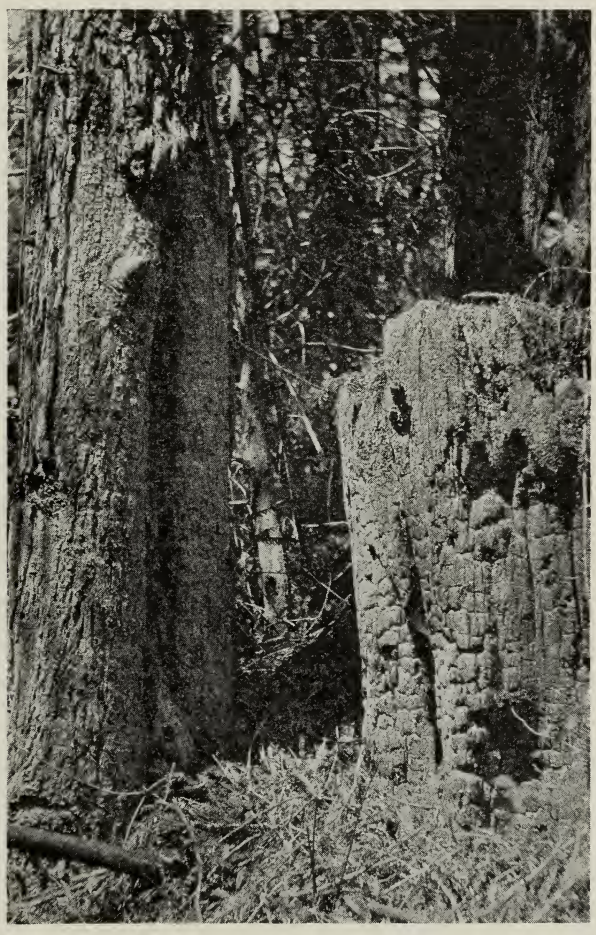

Fig. 7.—A common type of fire damage in the larger second growth. Fires burn most fiercely between the sprouts and parent stumps, and burn deeply into the butts as shown here. Behind the scar shown is rot which will ultimately extend far above the wound.

Natural seedlings do not occur plentifully in an old-growth forest and when found are usually on rotting logs or on heavy accumulations of humus. They occur, however, also on exposed raw soil where the virgin forest has been disturbed, especially along logging roads and fresh cuts and banks; in fact, raw soil seems to be a preferred

seed bed if there is some protecting shade. A fire will kill all the seedlings growing in the duff; some of those on exposed soil may sprout from the burl at the root collar of each plant unless the heat has penetrated too deeply.

FIRE MOST DESTRUCTIVE IN YOUNG GROWTH

As might be expected, the visible destructiveness of fires is most spectacular in young forests. Certainly it is more complete, and many promising stands of young growth have been wiped out by single fires. In the young growth the trees lack the protection of heavy bark, they stand closer to one another and to rotting mother stumps (fig. 7), their crowns are nearer the ground, there is usually more readily inflammable litter under them, and the soil in the early decades of the natural or artificial reforestation is ordinarily drier than in virgin forests. The fire hazard in such a forest is therefore much greater than in the old growth, and the protection effort must be correspondingly more intensive. A few of the more progressive lumber operators endeavor to keep fire out of cut-over land and young growth, but in general such growth is looked upon as of little consequence. If cut-over lands are not given better protection, the sprouting of redwood stumps becomes progressively weaker, seed trees are killed, and the slopes revert largely to brush species and can be returned to timber species only at great expense and with doubtful results. From an esthetic standpoint the loss is even more nearly complete.

REDWOOD FIRE PROBLEM COMPLICATED BY LOCAL ATTITUDE

The redwood fire problem should be viewed from the standpoints of three separate classes of people: (1) the non-timber owners, including local residents, local ranchers, hunters, and tourists; (2) timber owners not engaged in logging; (3) lumber companies engaged in logging, and 'split-stuff' operators.

Local residents, ranchers, and hunters are in the class already referred to, which believes in burning the woods to clear them of undergrowth to improve ingress or with the mistaken notion that the forest is thereby fire-proofed and its growth accelerated. Ranchers often resort to fire to clear their pasture lands of 'brush' which has encroached upon their lands largely due to mismanagement on their part rather than because of the proximity of the forest. For them

fire has a real function as a land-clearing medium but too frequently they look with impunity upon the escape of their ranch fires into a neighboring owner's timber. Occasionally local people set fires to improve the huckleberry crop, setting back the redwood sprout growth each time. Tourists occasionally start fires through carelessness or ignorance. Some build their camp fires in the hollow trees, accepting the belief that the trees are 'fireproof.' Local people as a rule have less respect for the redwood forest than those who live outside the region and come long distances to enjoy its magnificence.

Timber owners not engaged in logging include timber-owning ranchers and timber investors, some of the latter being very large companies. The investor is usually opposed to fire trespass but at the same time feels that little harm is done. This view is the result of a lack of appreciation or knowledge of the actual influence of fire upon the investment, as well as the result of a feeling of impotence in controlling incendiary fires. An investor who believes that fires do not impair his investment is deceiving himself. Timber-owning ranchers as a rule do not accept fire protection as a desirable procedure, and frequently deliberately thwart efforts of fire wardens to suppress fires.

Fires set by loggers as a part of their operations are in a separate category and are treated in the following paragraphs.

FIRES SET BY LUMBERMEN

Lumbermen have resorted to broadcast burning to consume slash since the earliest days of logging in the region (fig. 8). They discovered that fires burning over areas on which the trees have been felled but not yet removed, do not consume logs so completely as to make them a total loss as would be the case in other regions. There is such an enormous amount of potential lumber on an average redwood area, frequently over 100,000 board feet per acre, that if only half of it survived a fire the pioneer logger felt he was still ahead. The burning greatly facilitated the logging. In the early days the great volume of débris introduced a serious obstacle to the yarding operation conducted with animals or low-powered machinery. This débris problem is serious even today but some companies already feel it profitable to keep fire out at least until after the logs are removed. Even after logging and burning are completed there remain from 50 to over 90 cords of wood per acre, if one includes branches down to two inches in diameter. In the early days, also, little value

was attached to sapwood, practically all of which, along with some heartwood, is consumed in a 'hot' fire. Today, however, this material brings little less than the heartwood in the form of lumber. In recent years the leading lumber companies have become aware of the losses occasioned by fire and several are now maintaining fire control departments.

In split-stuff operations an effort is made to keep fire out of the woods until the removal of the split products—cross ties, posts, stakes, shakes, and shingle bolts. The débris on the ground consists

Fig. 8.—A cut-over canyon, shortly after the slash was burned and before the trunks were cut into log lengths. Most of the logs had been peeled before burning; the bright ones, after burning. This fire burned with more than usual intensity and caused great damage to the logs.

of the usual logging slash—tops, limbs, broken chunks, small felled trees, and the like—plus a huge volume of culled split products and chips, sticks, slabs, resulting from the splitting and broad-axing operations. Since no power equipment is used to move logs, many trees up to 36 inches in diameter at breast height and too small to work into split products are left standing. Many of them escape the slash fire at the close of the operation though not without injury. An abandoned split-stuff area, from a forestry standpoint, is in far better condition than an area logged off for saw logs, particularly as to the residual stand left. When a market was suddenly created a few years ago for redwood highway bridge piling, several split-stuff operators returned to their previously 'split-out' and abandoned areas to salvage the trees which survived the fires. To their disappointment,

however, they found these trees in most cases so badly fire-scarred at the bases, and infected subsequently by rot, that much loss occurred through the necessity of 'long-butting' or the rejection of entire trees after they were felled. An interesting sidelight (fig. 9) on this salvaging has a significant bearing upon forestry practice and offers

Fig. 9.—The butt end of a rejected 50-foot bridge pile cut from an area from which the larger merchantable trees had been removed nearly six years previously. This tree, then too small for a merchantable product, escaped subsequent slash fires but not without serious damage. At the time the surrounding competing trees were cut, this tree was 189 years old at the section shown, had a diameter of 13.5 inches and was growing at the rate of 1 inch in 26 years. The lessened competition stimulated the tree to accelerated growth and resulted in an increase in radius of 1.6 inches in only five years. New growth, however, could not take place over the fire scar but it was encroaching from the sides as is shown at *A*. The exposure of the old sapwood, *B*, has caused it to become decayed; eventually decay would have developed in the heartwood also.

conclusive proof of the writer's contention that redwood has an extraordinary power of accelerating its growth rate when freed from competition and this property should be taken advantage of in a changed system of logging. The trees surviving the fire, theretofore in a suppressed class and growing very slowly, had entered suddenly into the dominant class. They took advantage of the lessened competition and produced such an increased rate of growth, and conse-

quently such an increased width of sapwood, that the piling was rejected by the buyers' inspectors on a sapwood limitation specification. Though this worked a hardship in this particular case it gives excellent proof of the growth that may be expected from uncut trees in selectively logged operations, provided they are protected from damage by fire and logging. Redwood, *from a silvicultural standpoint,* is superior in the opinion of the author to any other American forest species in its adaptability to selective logging, but as in the case of other species it must be defended against fire.

On standard logging operations many trees are left standing because too small for profitable utilization. Their abundance is shown in the backgrounds of figures 3 and 4 and scattered in figure 8. In diameter they range from approximately 36 inches down to saplings. These trees are practically all destroyed in the yarding operation, figure 6, and represent a big loss on account of the present logging methods. However, should genuine selective logging[5] ever be practiced these trees must be protected from damage by fires. On split-stuff operations there is no destruction of similar trees by yarding, consequently an area that has been split-out has a considerable residual stand left. Such areas, however, are burned as severely as are logging areas.

Logging fires do great damage to logs not yet yarded (figs. 10, 11). When set before yarding and bucking they damage the fallen trunks frequently to the extent of 20 per cent of the merchantable volume if the bark has been peeled off. When the trunks are burned 'in the bark' the loss is, of course, considerably less. Should a fire be delayed until after the logs are made, the loss to merchantable lumber is increased by more than 5 per cent through burned ends and fires burning out logs containing rot. One large operator delayed burning until after logging but abandoned this practice after about eight years.

[5] The system of selective logging adopted recently by a few companies is of an economic type solely and has no silvicultural aspects. Under it the waste in the woods has increased and the damage to what should be a protected residual stand is almost as great as under the traditional system. It is purely *selective utilization* rather than even a crude 'selection system' of silviculture.

By way of definition, a selective cutting is one in which only certain trees are cut and removed, either from the standpoint of their maturity or from such economic dictates as market value, because of species, quality, size, or accessibility. Silviculture is the branch of forestry concerned with the treatment of forests for promoting their growth, development, and the production at low cost of valuable forest products. Silviculture applied to selective cutting would dictate a consideration of the effect of the method of cutting on the future of the forest. Silviculture is aided if the subsequent treatment of an area is such as to protect the trees left standing. Such trees give a 'running start' toward a second crop, and if sufficient in number will make planting unnecessary.

Fig. 10.—Influence of bark, also the lack of it, on damage by a slash fire. Where the bark was intact the wood was protected; where it had been stripped away the fire burned off 4 inches of wood leaving another inch of wood charred and causing many deep surface checks. The loss is equivalent to a diameter reduction of 10 inches on a 48-inch log.

Fig. 11.—Fire damage to down timber is greatest where two trunks lie close together. From four to six inches of wood have been burned from each of the two logs shown above where before the fire they were in contact.

Since then another large operator has determined upon delayed burning and at the same time has begun bringing the logs to the mill 'in the bark,' the bark being removed at central peeling plants. (The bark of redwood must be removed before sawing.) While no data are available on the effect of this policy on logging costs, observation points clearly to great savings in potential lumber output. Fires on peeled logs induce deep surface checking, while the occasional depressions burned into log sides where two logs cross or lie close together cause the development of much additional short-length lumber at the sawmills.

Fires on felled areas spoil the possibility of salvaging many small trees for poles for which a market should be developed. There is no good reason why redwood should not make as good a pole as western red cedar, the present standard pole species. Under present methods of logging and slash disposal the large-scale salvage of this product is hardly economical.

Slash fires cost money in wood destroyed and in the cost of their control by the woods crews. Their cost probably totals over $2.00 per thousand feet, log scale. This figure would be offset somewhat by an increased logging cost if slash is disposed of in another way. It is very desirable to inaugurate, without delay, experiments on different forms of slash disposal and to keep records of the cost and the effect upon logging as well as the use of the land for future timber yields.

Fire *must* be used in connection with logging, but it is all too evident that the present method of slash disposal is too destructive. Just what change can be effected economically is difficult to suggest. The entire area of a logging operation is a huge slash pile. Piling and burning, such as practiced in the California pine region, do not seem feasible. Perhaps burning the slash as it accumulates during the felling operation is the solution. Anyone who has viewed and considered the redwood slash disposal problem is impressed with the enormity of the job. Studies are urgently needed to determine less destructive methods of consuming the débris. Closer utilization would of course reduce the severity of the problem.

INFLUENCE OF FIRES UPON THE SOIL

Fires set by loggers to consume slash have a decidedly bad influence upon future growth. Such fires are made to run broadcast, and because of the heavy débris they burn fiercely and consume all the duff and humus along with the slash, brush, and young growth. Often there are two logging fires—one before the logs are removed to

simplify logging, and one following logging to clear the area of the accumulation of débris occasioned by yarding. Where reforestation by planting is practiced it is obvious that the débris must be removed. The experimental area already mentioned was burned three times before all the logs were removed. These fires leave the area absolutely devoid of green growth and potential seed trees. Soon after logging, however, bracken ferns, shrubs, perennial herbs, redwood stumps, and other deep-rooted plants sprout vigorously and many annuals like fireweed and Canada thistle, which thrive despite bad soil conditions, enter through seeding. The entry of dense masses of shrubs is almost inevitable under the present system of burning and logging and they increase the fire hazard immensely; however, they must be credited as important agencies for rehabilitating the soil, holding water, and checking erosion, and they therefore deserve protection despite their apparent lack of value. The top soil oftentimes has been so severely baked and has had most of its rich supply of the important macro- and microorganisms burned out of it that it is impotent for a long time to reproduce the more exacting seedling tree growth. Nursery-grown redwood plants, transplanted to such burned sites, suffer not only from exposure but also from the poor soil conditions in the surface layers. The dessication of the upper five or six inches during the long rainless season stunts the plants or causes the death of many. With no protection againt evaporation the upper layers become hard and compact, and unable, therefore, through reduced hygroscopicity, to benefit much from the large amount of atmospheric moisture of the region. The growing capacity of redwood soil is so high originally that the possibility of a reduced yield is overlooked. The reduction is, however, so great that the heavy annual growth which the soil is capable of producing in its virgin state is perhaps halved for two or three decades following its present treatment.

FORESTRY PRACTICE IS CONTINGENT ON CHANGED STANDARDS OF LOGGING AND BURNING

The discovery of a saner method of slash disposal than is now practiced is a necessary prelude to such selective logging as is intended to provide for a second cut. The logging method itself must be radically changed also, but this appears to be simpler than keeping the fires from injuring uncut trees and logs. *Correct forestry in the virgin stands of the redwood region should not require planting, yet*

correct forestry[6] *cannot be practiced until the engineering phase of logging is improved and slash fires are made less destructive.* It would appear then that the redwood region at present needs an engineer-forester even more than it needs a forester of the traditional order.

FIRES JEOPARDIZE TOURIST BUSINESS

The fire problem is closely bound up with the general business of the redwood region, much of which depends upon tourist traffic. Traffic on the Redwood Highway is increasing with such astounding rapidity that the roadway must be constantly improved to accommodate it. Most of the tourists are attracted by little else than an opportunity to view the justly famed redwoods. The impairment of this attraction through fire and destructive logging not only deprives the public of the inspirational and educational value of these great forests, but reacts against the local business people. It is analogous to killing the goose that laid the golden egg. From the middle of September to about December 9, in 1929, for example, the Redwood Highway region was so densely filled with smoke that tourists obtained only partial satisfaction from their visits and doubtless carried away enraged sentiments that will keep them from returning.

Clever advertising has created a wide desire to "see the redwoods." The public expects to find the beauty that is advertised. If the hillsides present only the ugly results of destructive logging methods and fires, if the remaining green timber is hidden behind a screen of smoke, or if the tourist entertains the fear of being drafted to fight fires, it is easy to see that local business people and not only the forests will suffer. The manager of a prominent redwood-region hotel told the author that his business drops off perceptibly during each period of heavy smoke. Service station proprietors on the Redwood Highway report likewise. The local business people thus have a stake in the redwood forests which they are not adequately appreciating and safeguarding.

[6] By 'correct forestry' the author implies a system of handling, like selective logging for example, which recognizes the great mixture of tree sizes in the virgin redwood forests and the greater potential value of those trees below the merchantable size, if left and protected, as against planted seedlings.

SUMMARY

There is no general fire consciousness in the redwood region, but a decided improvement can be noted particularly among operating companies. For several generations the feeling that "fires cannot hurt a redwood" has become so firmly established that attempts on the part of the state fire officials to extinguish fires are obstructed, especially by local ranchers and small timber owners. Incendiarism is practiced not so much with malice as with a real feeling that fires are necessary or desirable. Many local residents feel that fires actually do good in a redwood forest and look upon fires set by non-owners as a minor offense. The feeling that fire is not a serious menace to the redwood region has even influenced foresters to approve legislation which exempts this region from the operation of certain portions of state fire laws, and local legislators have thwarted recent attempts to place the redwood region on a parity with the balance of the state as to restricting the season for burning without permits. It is obvious, therefore, that the satisfactory correction of the fire problem, from the public standpoint, will not be a simple matter; otherwise, fire protection is no more difficult, except as to slash removal, than in other forested regions. The safety of the redwoods and the prosperity of the region are not secure so long as fires are looked upon with apathy and are permitted to be the dominant factor in influencing redwood growth.

The apathy toward fire in the redwood region is founded on fallacies. Fire has no place in the old-growth forest; it is particularly destructive to young forests, while on logging areas during the operations it should be more conservatively employed. Not only is valuable timber injured or destroyed, but the possibility for future timber crops is immensely reduced, while recreational values to the tourist are jeopardized. The lumber companies as well as local stores and hotels have a stake in tourist travel as much as they have in timber. It is time that the local county supervisors and chambers of commerce take cognizance of what fires mean to their communities and that they take vigorous steps to correct their regional fire problem. If they only work on changing the public apathy, and succeed, their fight for complete protection of the redwoods is more than half won. Certainly the winning of public sentiment for fire protection should precede the passage of more laws which might only invite an increase in incendiarism.

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